

Modeling AGN spectra with PHOENIX: a self-consistent approach

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Abstract.

We find that spectra of certain Iron Low Ionization Broad Absorption Line (FeLoBAL) QSOs, which are characterized by low-ionization emission and blue shifted absorption lines, can be well matched with the spectral synthesis code SYNOW. SYNOW is a resonance scattering code and assumes that line emission comes from a single line forming region. This interpretation is novel as traditionally line emission and absorption in BALQSOs are thought to come from two different regions. We extend this analysis by using the detailed PHOENIX code to model the spectra. We present a SYNOW fit and a preliminary model result from PHOENIX.

1. Introduction

It may be that the FeLoBAL QSO phenomenon is a phase in which the central super-massive black hole is strongly obscured by the surrounding material. The spectra of some of these objects are indeed redder than the spectra of typical AGN, which could signify thermal re-processing of the underlying central-engine emission. At some point, due to either an ejection event or a wind, the outer envelope of this cloud would be blown away. In the spectra of these objects we see spectral features that appear to be consistent with this. In fact, they appear much the same as the P-Cygni profiles that are seen in objects that have winds. We present models that are consistent with this scenario.

2. Computer modeling

We are beginning to model FeLoBALs, assuming a single spherically symmetric line forming region, with SYNOW and PHOENIX in an attempt to to understand more about their physical properties.

SYNOW is a parameterized spectral synthesis code used for line identification in spectra of supernovae and supernova-like events. The major assumptions are spherical symmetry, v (velocity) $\propto r$ (radius), and that the line source functions are those of resonance scattering. SYNOW's strengths are speed and inclusion of multiple scattering while using a large atomic line list. It is difficult, however, to quantitatively interpret the results of SYNOW in terms of physical parameters.

PHOENIX assumes a one-dimensional atmosphere either in spherical or slab geometry. PHOENIX's greatest strength is its self-consistent solution of the radiation field with the NLTE atomic level populations. PHOENIX requires only a few input parameters, most of which are observable. This can result in a high degree of physical realism.

PHOENIX can be used with LTE or NLTE level populations. With PHOENIX we match observables with the initial boundary conditions in the hope of deriving realistic physical parameters. The boundary conditions are the luminosity and the pressure at the outside of the atmosphere. Input parameters include: the maximum velocity of the ejecta, the chemical compositions, etc. In addition PHOENIX can use a variety of velocity laws for the atmosphere including those used in winds and supernovae. PHOENIX calculates the spectrum self-consistently therefore providing reliable information about temperatures and densities, and the kinetic energy and mass-loss rate for the ejected atmosphere.

3. Analysis

We have used SYNOW to fit the spectrum of ISO J005645.1-273816 (Duc et al. 2002) identifying lines of C III, Mg II, Al III, Si II, Cr II, Fe II, Fe III, and Ni II (Figure 1). In the synthetic spectrum, almost all of the features that are not labeled are produced by Fe II. The model has a velocity at the photosphere of 1500 km s^{-1} , a power law optical depth distribution with index of -2 , and an excitation temperature of 7000 K . The two emission spikes in the observed spectrum that are marked with crosses are spurious.

The spectrum of another FElLoBAL, FBQS1214+2803 (White et al. 2002) was studied with SYNOW by Branch et al. (2002), who emphasized the need for a more detailed self-consistent calculation. We have calculated a PHOENIX model for FBQS1214+2803 with the following physical parameters: a luminosity of $L=6 \times 10^{46} \text{ ergs s}^{-1}$, which with an effective temperature of 7000 K corresponds to a radius of $4 \times 10^{17} \text{ cm}$. We used $v_{max} = 2600 \text{ km s}^{-1}$, $v \propto r$, solar metallicity, LTE, and a power law density structure with an index of -8 . This density structure is probably more correct for an ejection event than a wind and in the future we intend to explore other density distributions such as -2 which would be expected for a wind. The pressure at the surface is set to be $1 \times 10^{-12} \text{ ergs cm}^{-3}$. So far we have only investigated the region of the Mg II doublet. With this set of parameters and boundary conditions we can clearly see the Mg II feature (Figure 2). However, the Mg II optical depth appears to be too low and the emission peak is slightly blue-shifted perhaps due to the absorption feature of a redder line. This may be fixed by introducing NLTE and finding a more adequate realization of physical conditions that increase the optical depth of Mg II and reduce the optical depths of other features.

Given the input parameters above our model implies a mass loss rate of $5 \times 10^5 M_{\odot} \text{ yr}^{-1}$. This is high, and if correct may imply an ejection event. However, these are preliminary models and with a more satisfactory set of input parameters the final result will differ.

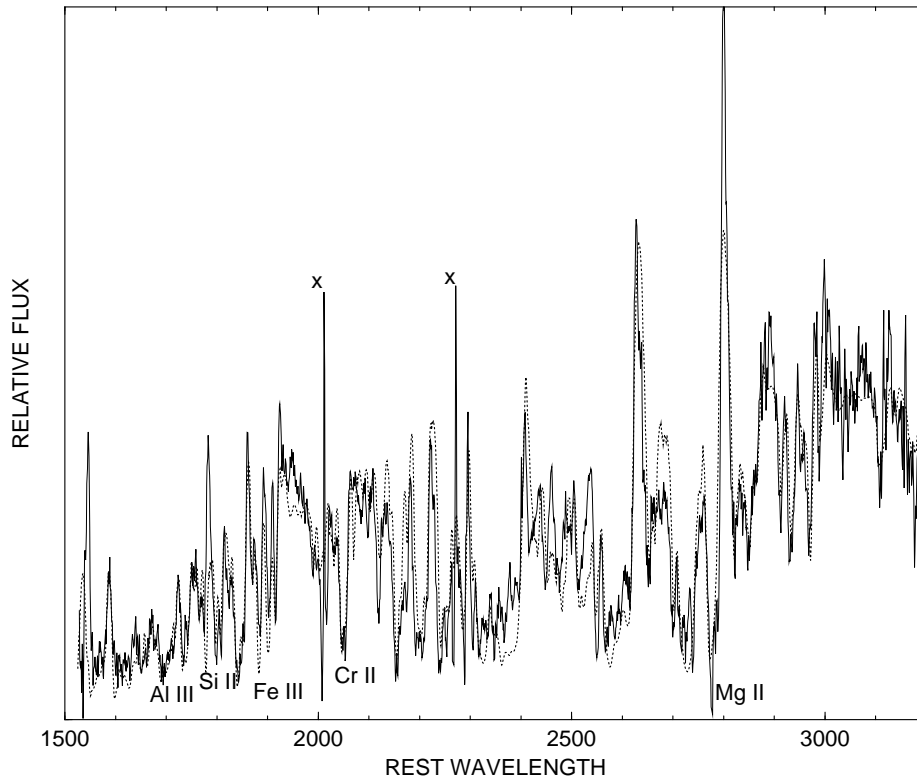


Figure 1. The spectrum of ISO J005645.1–273816 from Duc et al. (2002) (*solid line*) is compared with a SYNOW synthetic spectrum (*dotted line*)

4. Conclusion

We have shown that the resonance scattering interpretation of at least some FeLoBAL spectra needs to be considered. In particular, the SYNOW model of ISO J005645.1–273816 is superb. However much more work needs to be done. We need to do NLTE calculations and explore additional density and velocity structures. We also need to model ISO J005645.1–273816 and other FeLoBALs to learn the extent to which the resonance scattering interpretation is applicable.

References

- D. Branch, K. Leighly, R.C. Thomas, E. Baron, 2002, *AJ*, 578, L37-L40
P.-A. Duc, P.B. Hall, D. Fadda, P. Chaniel, D. Elbaz, P. Monaco, E. Pompei,
B.M. Poggianti, H. Flores, A. Franceschini, A. Biviano, A. Moorwood, and
C. Cesarsky, 2002, *A&A*, 389, L47-L50
R.L. White et al., 2002, *ApJS*, 126, 133-207

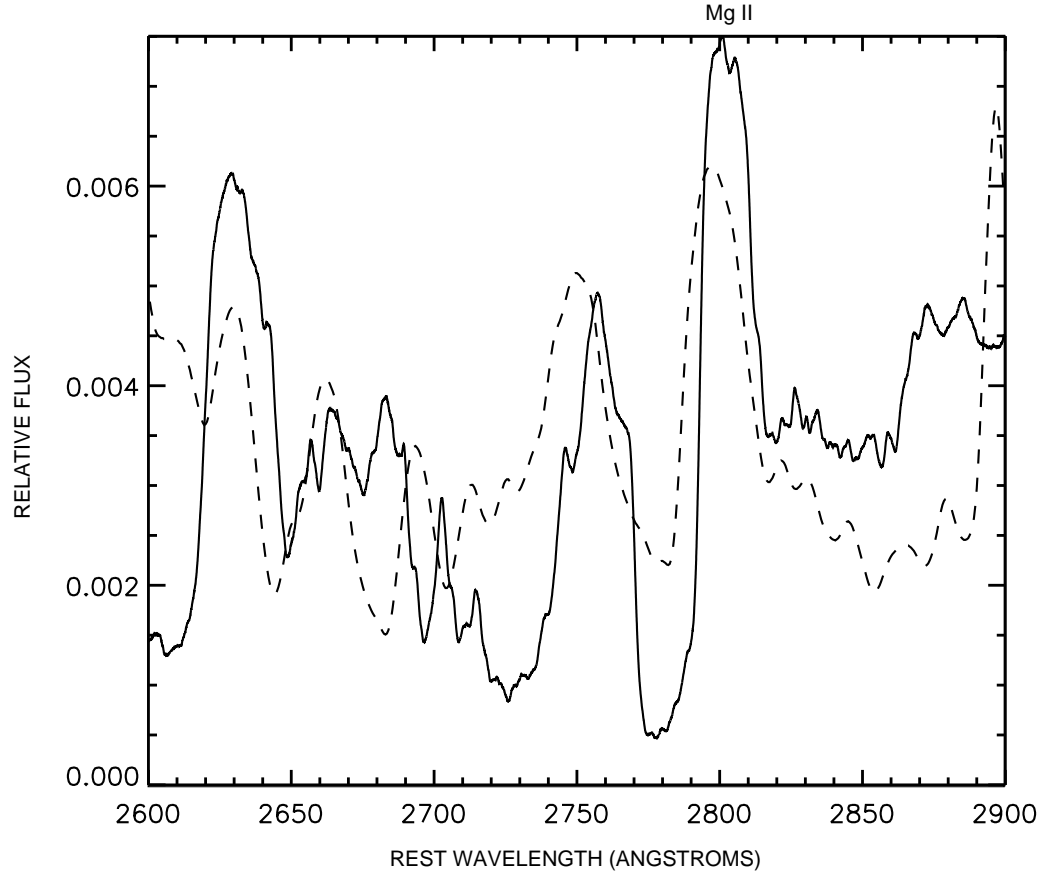


Figure 2. The spectrum of FBQS 1214+2803 (*solid line*) is compared with a synthetic spectrum calculated with PHOENIX (*dashed line*).